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**Final Technical Report**  
**NASA ROSAT Guest Observer Program**  
**AO1**

**Grant Titles:** "Surface Brightness Profiles and Energetics of Intracluster  
Gas in Cool Galaxy Clusters"  
&  
"ROSAT Observations of Bright, Early-Type Galaxies"

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**Period of Performance** 1 August 1991 - 14 August 1994

I was awarded Priority C time to observe a total of two objects associated with two different observing proposals in *ROSAT* AO1: the galaxy NGC 5846 was associated with the proposal *ROSAT Observations of Bright, Early-Type Galaxies* and the galaxy cluster A576 was associated with the proposal *Surface Brightness Profiles and Energetics of Intracluster Gas in Cool Galaxy Clusters*. However, mechanical problems with *ROSAT* prevented these two scheduled observations from being performed successfully. The grant funding was initiated when the observing logs indicated that the first observation (A576) was successfully performed. However, information later made public (in the form of a “black list”) indicated that the object was pointed at, but no data were taken due to a malfunction. My remaining observation was bumped due to downtime from the loss of a gyro. The fact that both targets were priority C meant that the objects would not be rescheduled without reproposing. Meanwhile, I had already been awarded an additional target (elliptical galaxy NGC 1407) under *ROSAT* AO2. After consulting with *NASA* administrators, it was agreed that I could use AO2 funds to buy a workstation to support my AO2 data analysis, and AO1 funds could be used to provide summer salary and travel support for my AO2 project. After these early mechanical troubles with *ROSAT*, and in time for AO2, *NASA* changed the funding policy so grant funding would be initiated only after the associated X-ray photons had been *confirmed* to have been collected by the telescope! Following is an account of some of the work subsidized by my *ROSAT* AO1 grant.

Preliminary results on the elliptical galaxy NGC 1407 were published in the proceedings of the first *ROSAT* symposium (White et al 1994). NGC 1407 is embedded in diffuse X-ray-emitting gas which is extensive enough that it is likely to be related to the surrounding group of galaxies, rather than just NGC 1407.

Spectral data for NGC 1407 (AO2) and IC 1459 (AO3) are also included in a complete sample of elliptical galaxies I compiled in collaboration with David Davis (Davis & White 1996, 1998; White & Davis 1997,

1998). I found that the 43 optically brightest ellipticals (outside the zone of avoidance  $|b| < 20^\circ$ ) have X-ray data, with *ROSAT* PSPC data available for 38. This allowed us to construct the first complete X-ray sample of optically-selected elliptical galaxies. The complete sample allows us to apply Malmquist bias corrections to the observed correlation between X-ray and optical luminosities. We find that X-ray luminosities  $L_X$  rise more steeply with optical (blue) luminosities  $L_B$  than found in previous studies of incomplete samples.

Davis & I were also able to determine temperatures for 30 of the galaxies in this complete sample (29 PSPC temperatures, 1 from *Einstein* IPC). We find that the X-ray emitting gas is always hotter than the kinetic temperature of the stars; this is likely due to the luminous parts of the galaxies being embedded in dark matter halos characterized by larger velocity dispersions than the luminous stars. As the publication list below indicates, I continue to work on the implications of this first complete X-ray sample of elliptical galaxies.

Paul Eskridge, Dave Davis and I also analyzed three long *ROSAT* PSPC observations of the small (but not dwarf) elliptical galaxy M32. We were able to assess its X-ray variability on a large range of timescales since we also compared the *ROSAT* results to decade older *Einstein* observations. The dominant X-ray source in M32 is very near the center of M32 and is indeed variable on timescales ranging from minutes to a decade. We found the X-ray spectra and variability to be consistent with either a low mass X-ray binary (LMXRB) or a putative “micro”-AGN. Subsequent work by Davis and Loewenstein favors the LMXRB hypothesis.

## Publications

- *Dark Matter in the Elliptical Galaxy NGC 1407*  
R.E. White III, V.A. Andersen, & C. Williamson 1994, in *The Soft X-ray Cosmos*, eds. E. M. Schlegel & R. Petre (New York: AIP), pp. 353-354

- *ROSAT Temperatures & Abundances for a Complete Sample of Elliptical Galaxies*  
D.S. Davis & R.E. White III 1996, *Astrophys.J.Letters*, **470**, L35-39.
- *X-ray Properties of a Complete Sample of Elliptical Galaxies: Implications for Cooling Flow Models*  
R.E. White III & D.S. Davis 1997, in *Galactic & Cluster Cooling Flows*, ed. N. Soker, A.S.P. Conf. Series volume 115 (San Francisco: A.S.P.) pp. 217-226.
- *X-ray Emission from M32: X-ray Binaries or a microAGN?* P.B. Eskridge, R.E. White III, D.S. Davis 1996, *Astrophys.J.Letters*, **463**, L59-62.
- *X-ray Emission from M32: X-ray Binaries or a microAGN?* P.B. Eskridge, R.E. White III, D.S. Davis 1995, *Bull.Amer.Astron.Soc.*, **27**, 1354
- *X-ray Properties of a Complete Sample of Elliptical Galaxies: Implications for Dark Matter Halos*  
R.E. White III & D.S. Davis 1998, to appear in *Galactic Halos*, ed. D. Zaritzky, A.S.P. Conf. Series.
- *X-ray Properties of a Complete Sample of Elliptical Galaxies*  
D.S. Davis & R.E. White III 1998, to be submitted to the *Astrophys.J.*

#### Conference Talks & Poster Presentations

- *Dark Matter in the Elliptical Galaxy NGC 1407*  
R.E. White III, V.A. Andersen, & C. Williamson (November 1993)  
poster presented at meeting on *The Soft X-ray Cosmos*, College Park, Maryland
- *X-ray Properties of a Complete Sample of Elliptical Galaxies: Implications for Cooling Flow Models*  
R.E. White III (August 1996) invited talk given at meeting on *Galactic & Cluster Cooling Flows*, Oranim, Israel

- *X-ray Properties of a Complete Sample of Elliptical Galaxies: Implications for Dark Matter Halos*  
R.E. White III (August 1997) talk given at meeting on *Galactic Halos*, Santa Cruz, California